SOFTWARE FOR APSU LLRF

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In collaboration with
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OUTLINE

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UPGRADE OF LLRF

Upgrading APS from Analog to Digital LLRF

- Storage Ring

- Booster

- Particle Accumulator Ring
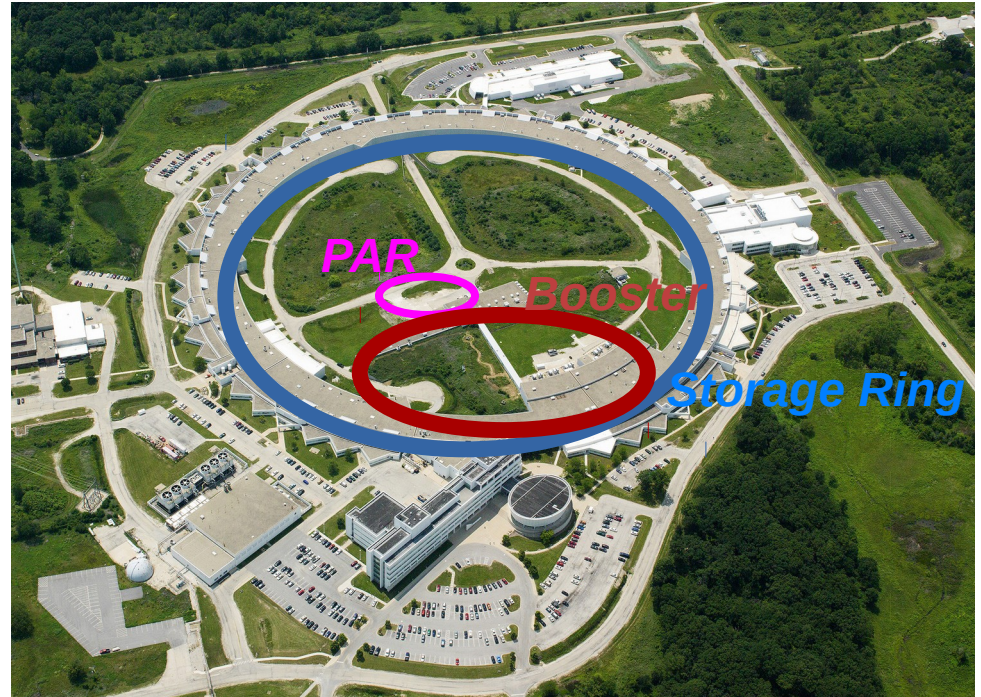
COMMON MICRO-TCA PLATFORM

- FPGA Advanced Mezzanine Carrier (AMC) with RF FPGA Mezzanine Cards (FMC)

  - FPGA firmware developed at Oak Ridge National Laboratory

- PCIe 4x Backplane

- Linux Blade running EPICS 7 IOC

- Common Hardware for APS Machines (PAR, SR, Booster)

- Common Software Platform

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OUTLINE

- Introduction and Background

- **APS Data Acquisition Software Infrastructure**

- The LLRF EPICS 7 IOC

- User Interface

- Thanks

SOFTWARE INFRASTRUCTURE

Experimental Physics and Industrial Control System (EPICS)

- Distributed digital control system

- Version 3 controls APS

- Input-Output Controller (IOC)

  - Computer that connects to hardware and publishes "Process Variables" (PVs) on network.
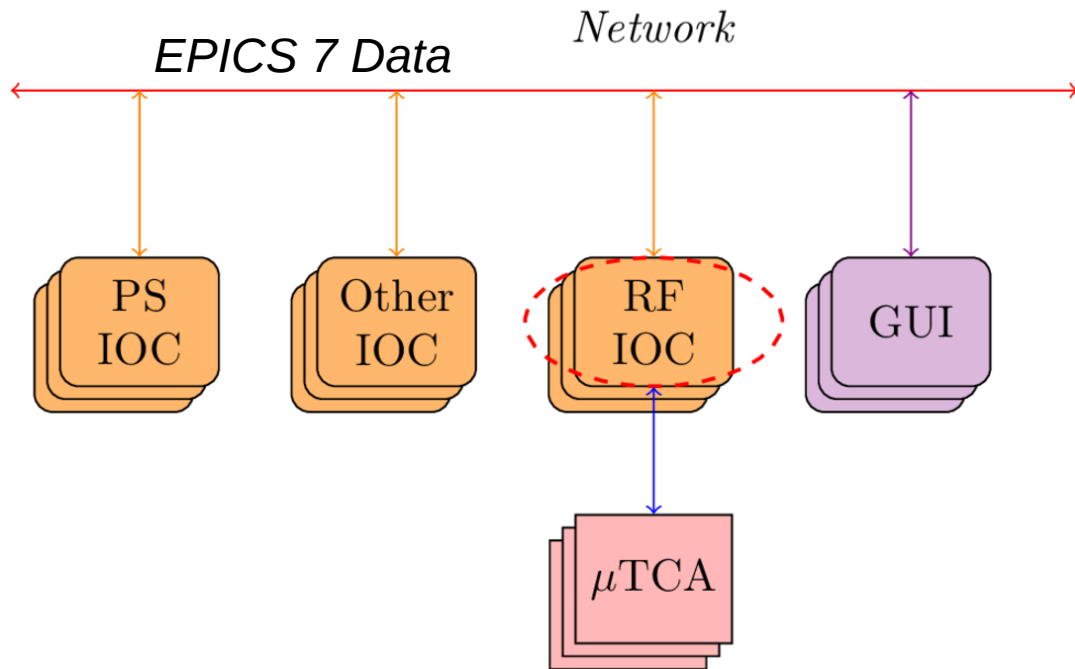
- Clients access PVs

  - GUI or Scripts to control Accelerator Systems.
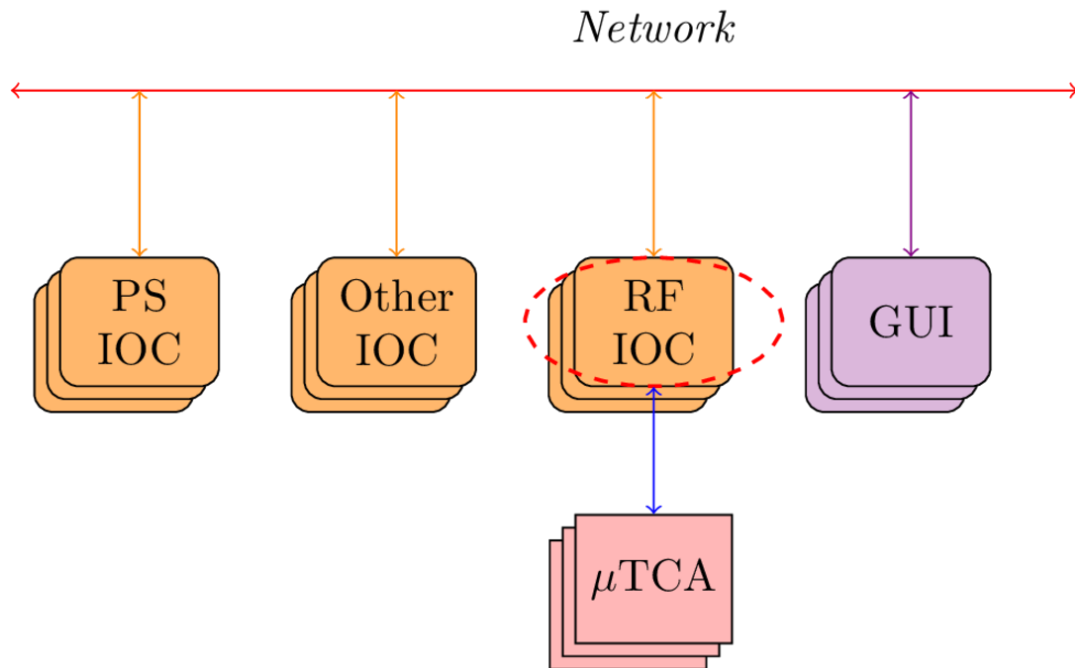
SOFTWARE INFRASTRUCTURE

Experimental Physics and Industrial Control System EPICS

- Version 4 adds

  – Structured Data

  – Reliable Data Streaming

- EPICS 3 + 4 = 7

  LLRF_Data {
  float Sample Rate;
  float [ ] I_Data;
 *float [ ] Q_Data;*
  float [ ] Mag;
  float [ ] Phase;}

Network

EPICS 7 Data

PS IOC · Other IOC · RF IOC · GUI · μTCA

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SOFTWARE INFRASTRUCTURE
EPICS Area Detector for EPICS 7 Accelerator Data

- Area Detector

  - EPICS tools for acquiring images from large x-ray detectors.

  - IOC with Driver and set of Plug-ins.

  - Image passed between Driver and Plug-ins on queues

- AD + EPICS 4

  - Pass EPICS 4 accelerator data rather than images

- AD+EPICS 7 is basis of APS software infrastructure

DAQ IOC

EPICS 4 Data passed on queues between Plug-ins.

Driver controls and reads data from Hardware

All arrows are Queues
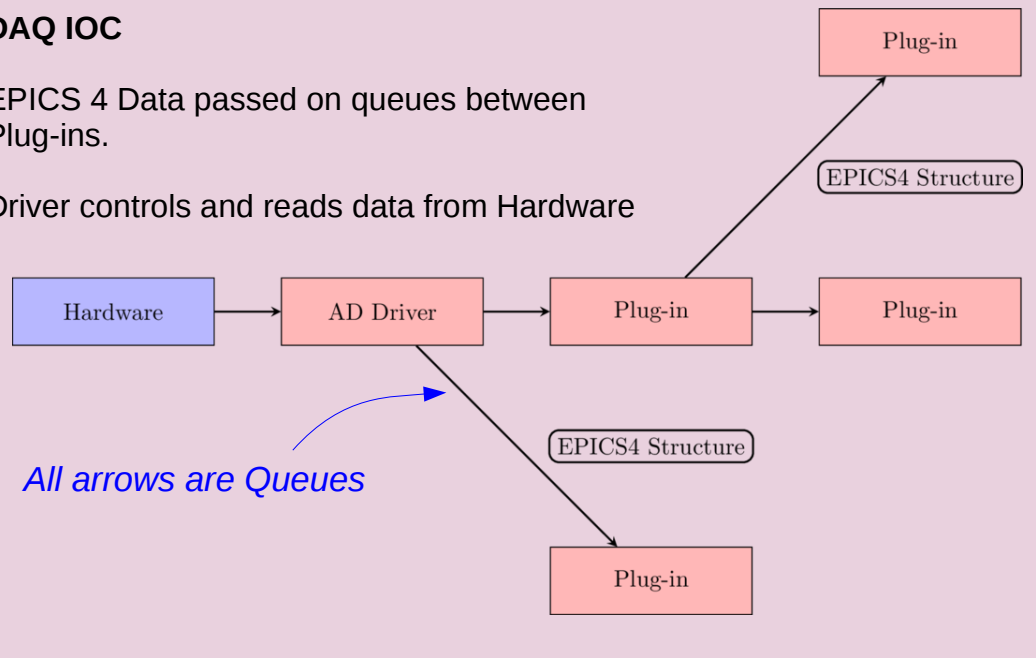
SOFTWARE INFRASTRUCTURE

Data Acquisition System (DAQ)

- Many EPICS 7 IOCs

- Network Services

  - Data Forwarding

  - Data Storage

  - Data Processing

  - Others

- Time Stamping System

- Real-Time Visualization

- User Command Line Tools

- Many Data Protocols
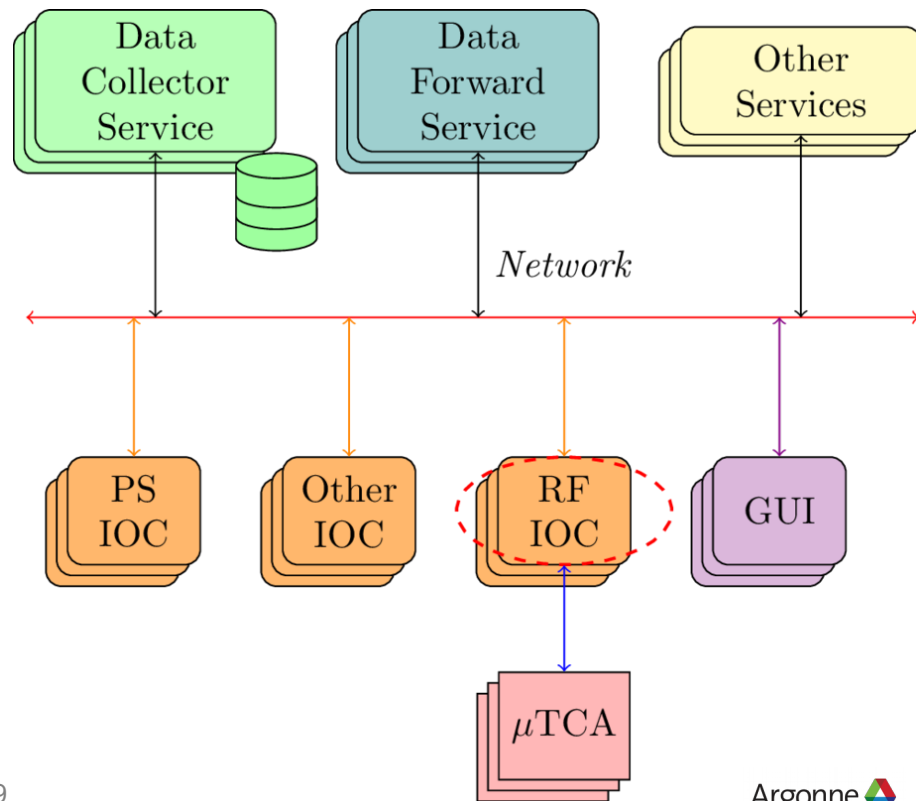
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LLRF IOC

Software Stack

- Micro-TCA crate send/receive PCIe

- OCC Kernel module (red) handle PCIe Data

    - Linux use OCC module for DMA.

    - OCC library allow IOC access to PCIe data.

    - Developed at Oak Ridge National Laboratory

- IOC (blue)

    - Control Micro-TCA via EPICS3

    - Get PCIe data, convert to EPICS4 I/Q data.

    - Stream EPICS4 over network.
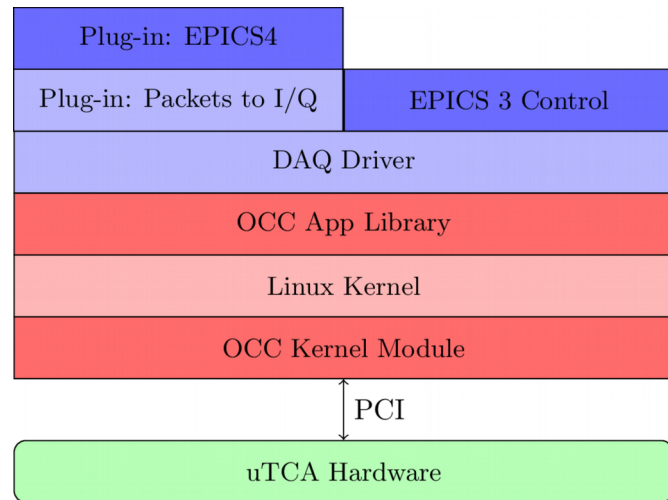
LLRF IOC

Automatic Screen and Code Generation

- Synchronize Software Development at ANL with Firmware Development at ORNL.

- Work flow:

  – Update Firmware and Compile

  – Document in Spreadsheet

  – Run Python

  – Compile Software

  – Run new IOC Driver SW.

LLRF IOC

PCIe Packet

- PCIe Packet Format for DMA
- Real Time Streaming of I/Q Data
- Header in Green
  - Time stamp info.
  - Sample Rate info.
- 16 Channels of Data in Blue

LLRF IOC

Real Time Data Flow

- FPGA runs PID RF Control loop
  - Controls RF mag/phase in cavities

- Wave forms taken from several points in PID loop.

- For loop setup, diagnostics, monitoring.

- Real-time streaming of I/Q, Mag/Phase data.
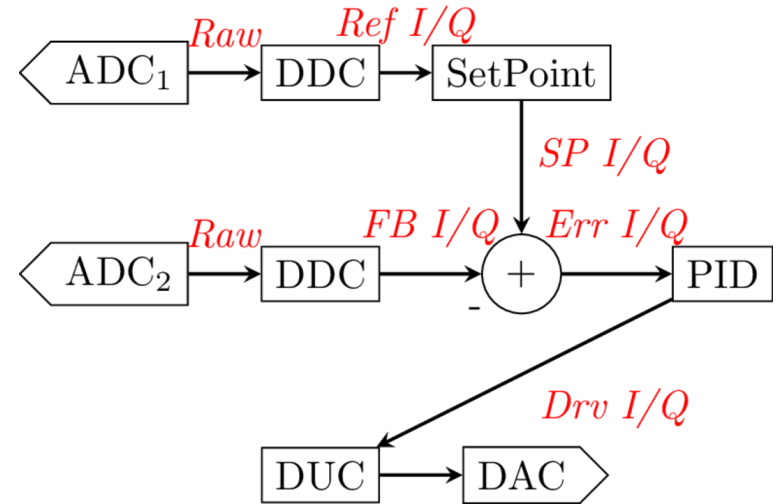
In Red are signals streamed from PID loop.

LLRF IOC
Real Time Processing

- Driver runs on designated core

  - Gets PCIe packets from OCC and places in queue

- Processing Plug-in

  - Parse PCIe packets

  - Create I/Q wave forms in EPICS 4 Structures

  - Calculate Phase/Magnitude vectors in EPICS 4

- Streaming Plug-in

  - Stream I/Q, Phase/Mag as EPICS4

  - For file store, real-time display
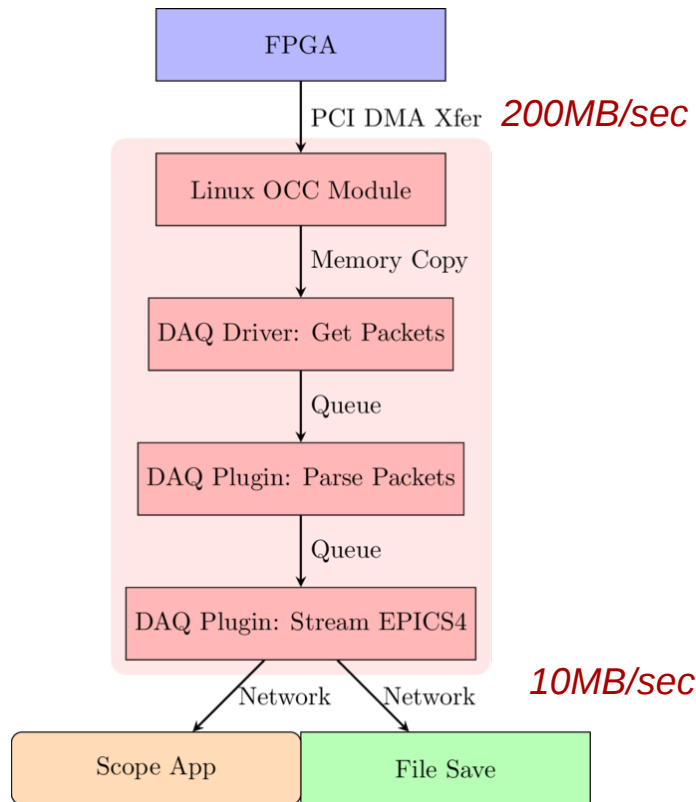
FPGA

PCI DMA Xfer *200MB/sec*

Linux OCC Module

Memory Copy

DAQ Driver: Get Packets

Queue

DAQ Plugin: Parse Packets

Queue

DAQ Plugin: Stream EPICS4

Network   Network   *10MB/sec*

Scope App   File Save

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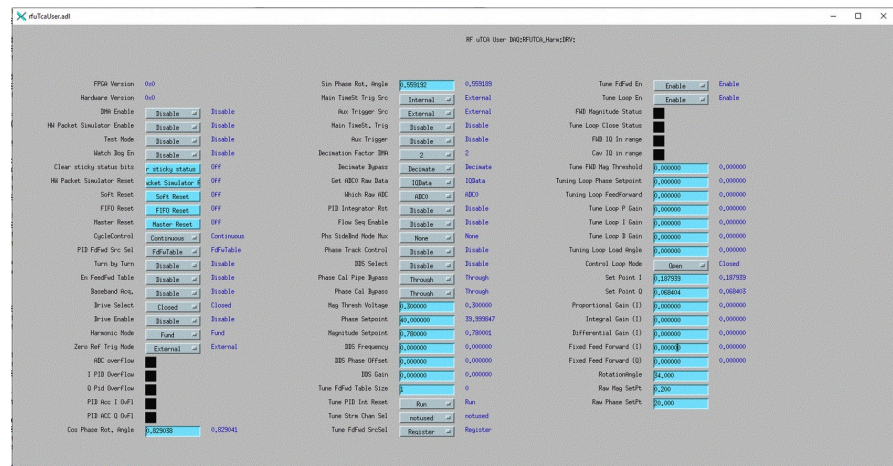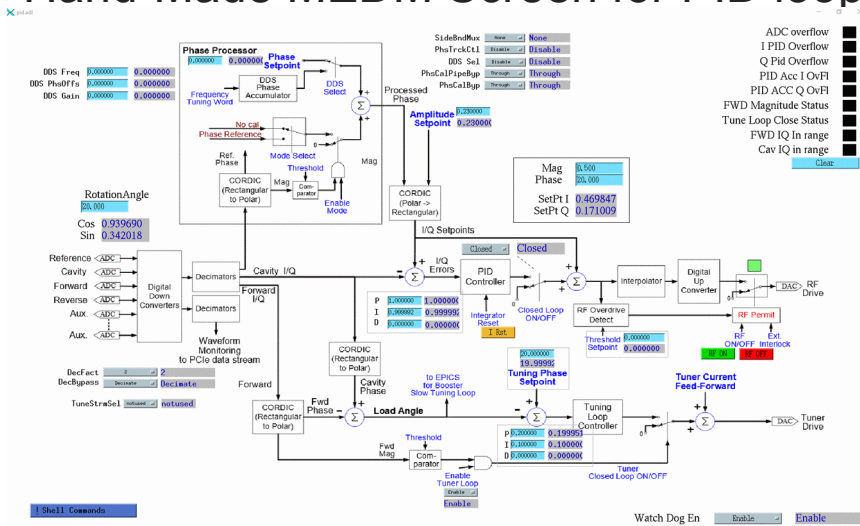- **User Interface**

- Thanks

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USER INTERFACE

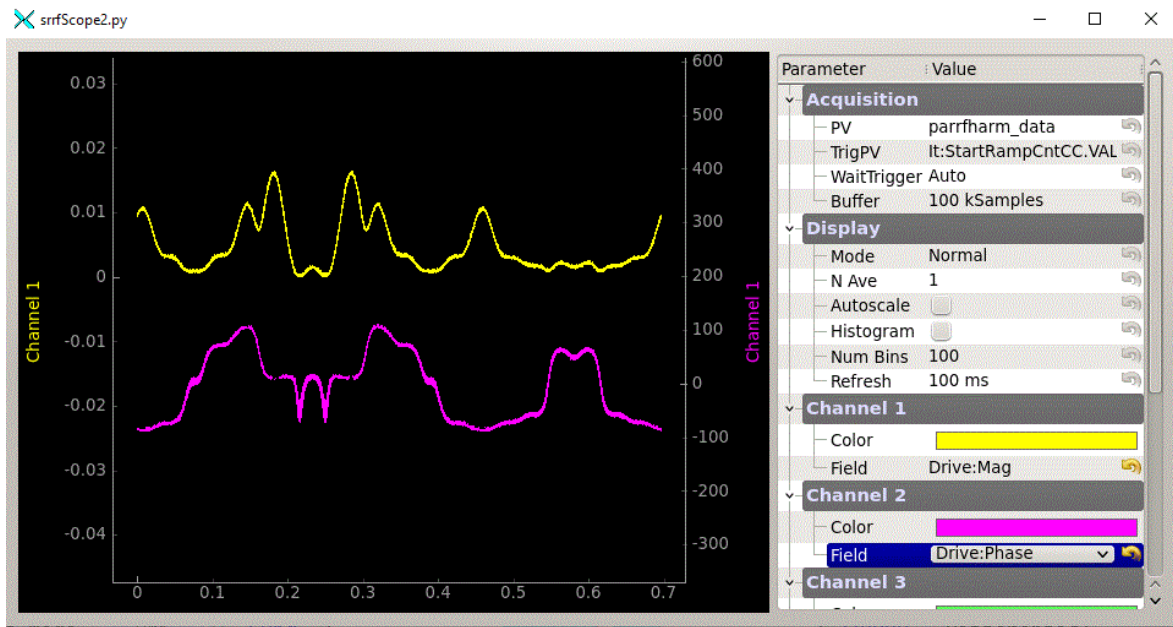## Control GUI

- Auto-Generated MEDM Screens
- Hand-Made MEDM Screen for PID loop.

USER INTERFACE

Scope Application

- Real-Time Display of I/Q, Phase/Mag wave forms.
- Time or Frequency Domain
- Trace averaging
- Up to Four waves at once.
- Triggered on EPICS PV
  - 2Hz Booster cycle trigger scope.

THANK YOU FOR LISTENING

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